Thermoelectricity

Alternative Titles: Peltier-Seebeck effect, thermoelectric effect

Thermoelectricity, also called **Peltier-Seebeck effect**, direct conversion of heat into electricity or electricity into heat through two related mechanisms, the Seebeck effect and the Peltier effect. When two metals are placed in electric contact, electrons flow out of the one in which the electrons are less bound and into the other. The binding is measured by the location of the so-called Fermi level of electrons in the metal; the higher the level, the lower is the binding. The Fermi level represents the demarcation in energy within the conduction band of a metal between the energy levels occupied by electrons and those that are unoccupied. The energy of an electron at the Fermi level is $-W$ relative to a free electron outside the metal. The flow of electrons between the two conductors in contact continues until the change in electrostatic potential brings the Fermi levels of the two metals (W_1 and W_2) to the same value. This electrostatic potential is called the contact potential ϕ_{12} and is given by $e\phi_{12} = W_1 - W_2$, where e is 1.6×10^{-19} coulomb.

If a closed circuit is made of two different metals, there will be no net electromotive force in the circuit because the two contact potentials oppose each other and no current will flow. There will be a current if the temperature of one of the junctions is raised with respect to that of the second. There is a net electromotive force generated in the circuit, as it is unlikely that the two metals will have Fermi levels with identical temperature dependence. To maintain the temperature difference, heat must enter the hot junction and leave the cold junction; this is consistent with the fact that the current can be used to do mechanical work. The generation of a thermal electromotive force at a junction is called the Seebeck effect (after the Estonian-born German physicist Thomas Johann Seebeck). The electromotive force is approximately linear with the temperature difference between two junctions of dissimilar metals, which are called a thermocouple. For a thermocouple made of iron and constantan (an alloy of 60 percent copper and 40 percent nickel), the electromotive force is about five millivolts when the cold junction is at 0 °C and the hot junction at 100 °C. One of the principal applications of the Seebeck effect is the measurement of temperature. The chemical properties of the medium, the temperature of which is measured, and the sensitivity required dictate the choice of components of a thermocouple.

The absorption or release of heat at a junction in which there is an electric current is called the Peltier effect (after the French physicist Jean-Charles Peltier). Both the Seebeck and Peltier effects also occur at the junction between a metal and a semiconductor and at the junction between two semiconductors.

The development of semiconductor thermocouples (e.g., those consisting of *n*-type and *p*-type bismuth telluride) has made the use of the Peltier effect practical for refrigeration. Sets of such thermocouples are connected electrically in series and thermally in parallel. When an electric current is made to flow, a temperature difference, which depends on the current, develops between the two junctions. If the temperature of the hotter junction is kept low by removing heat, the second junction can be tens of degrees colder and act as a refrigerator. Peltier refrigerators are used to cool small bodies; they are compact, have no moving mechanical parts, and can be regulated to maintain precise and stable temperatures. They are employed in numerous applications, as, for example, to keep the temperature of a sample constant while it is on a microscope stage.